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RESEARCH IN WATER SUPPLY AND WATER POLLUTION AT THE ROBERT A. TAFT SANITARY ENGINEERING CENTER

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

1 August 1959

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Robert A. Taft Sanitary Engineering Center Technical Report W59-3

RESEARCH IN WATER SUPPLY AND WATER POLLUTION

at the

ROBERT A. TAFT SANITARY ENGINEERING CENTER

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U. S. DEPARTMENT OF HEALTH,
EDUCATION, AND WELFARE
Public Health Service

Research in Water Supply and Water Pollution

A survey of projects currently being conducted by the Research Branch, Division of Water Supply and Pollution Control, at the Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio.

Details of illustrations in this document may be better studied on microfiche.

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

Public Health Service

Bureau of State Services

Robert A. Taft Sanitary Engineering Center

Cincinnati, Ohio

August 1, 1959

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FOREWORD

The protection of the Nation's water resources ranks high as a public health problem. For decades the Sanitary Engineering Center and its predecessor organizations have been concerned with water quality, and they have made significant contributions to the safety of our water supplies. However, the pattern of our problems is changing rapidly, and it is important that we review and adjust our approaches accordingly.

When the Stream Investigations Station was established in Cincinnati in 1913 by the Public Health Service, the Industrial Revolution in the United States had been in progress for approximately a century. Water pollution was already a recognized problem. The first years of research were devoted to the definition of existing problems, to the accumulation of basic theoretical knowledge, and to the development and application of corrective measures.

These have been accomplished with reasonable success. Basic water pollution measurements including the oxygen demand criteria were developed and applied. Techniques for the treatment of urban wastes were evolved or refined. And a great deal of progress has been made, especially in recent years, in the installation of plants to treat wastes before they are released into our water resources.

Today techniques are available for dealing with many of the traditional urban pollution problems. This has resulted from the efforts, not only of the Public Health Service, but of several branches of the Federal government, of state and local government at every level, of universities, and of many farsighted industrial and civic organizations. Research should eventually produce solutions for the residual problems.

Now, almost suddenly it seems, we find ourselves confronted with new and difficult challenges. It is being demonstrated, almost on a day to day basis, that in a society such as ours even the pollution problems are dynamic. New, or newly recognized, water supply and water pollution research problems have developed. It is apparent that we must learn more about the relationships between our water resources and synthetic chemicals, viruses, and radiological wastes, and about water quality management in the face of competing demands for the same supply. Most disturbing of all is the prospect of accommodating a limited supply of water to our expanding population and the industrial growth which will be needed to support it.

The synthetic organic chemicals for the most part are not removed by our present "modern" water treatment plants. We know little about the current or potential impact of these chemicals in water upon man's health--at what concentrations the "breakpoint" of tolerance will occur. As with food protection, epidemiologic and toxicologic research is needed to provide a sound basis for health agency action.

Through improved and more extensive sewage treatment and better water treatment practices we have been able to hold the line with regard to bacterial quality. This confidence may not be extended to viruses whose role in water sanitation has not been clearly defined. We have seen the first reported outbreak of infectious hepatitis, a virus disease, in a major city having modern water treatment facilities, New Delhi, India.

Our industrial expansion has been closely related to an accelerating increase in fuel use or energy available for production of goods. Even at the present rate, a ten-fold increase over 100 years ago, we will have to look to new energy sources in the near future. The most apparent one is nuclear energy in the form of reactors generating power for industrial use. These plants will be substantial users of water for cooling and other purposes, and we must concern ourselves with the radioactive and thermal pollution which may result.

Since man is dependent on water to satisfy his wants and dispose of his wastes, it is evident that competition for this key resource will

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increase with growth of the nation. More skillful planning and management will be needed to keep in balance the many competing water demands: for municipalities, industries, municipal and industrial waste disposal, commercial and sport fishing, recreation, wildlife, agriculture, navigation, and power. Flood and drought serve to complicate the problem.

While protecting water quality is a major problem it actually takes the form of several major problems, including quantity and reuse. We are adding the equivalent of a city the size of Chicago to our population each year, and our economy is pushing rapidly toward a $600 billion annual gross national product. We are using more water and we are forced to use it more intensively. With water requirements scheduled to double by 1975, we will be bumping the ceiling of available supply. This is today's problem. It calls for action now to develop ways of using water more prudently, and for ways of reusing it; for bolder ways of distributing it over long distances if need be, as with electricity, natural gases, and oil; and above all for much sound planning.

Our progress to date in water supply and water pollution has been a joint effort of many groups. I hope that these brief summaries of the research projects underway at the Sanitary Engineering Center will further the cooperative approach to the problems which we now face.

Harry G. Hanson, Director
Robert A. Taft Sanitary Engineering Center

PREFACE

As the primary Federal laboratory concerned with research in water supply and water pollution, the Robert A. Taft Sanitary Engineering Center has endeavored to build a program which realistically meets both regional and national needs.

This has involved diversification in several directions. As can be determined from the major projects included in this report, research activities are concerned with population units ranging from the individual household to the large areas of the Nation.

Our research also involves many of the major scientific disciplines. The present water supply and water pollution research professional staff numbers 60 and includes competency in engineering, chemistry, physics, microbiology, aquatic biology, epidemiology, toxicology, and statistics. An equal number is included in the supporting staff.

Laboratory and administrative offices for water supply and water pollution research occupy 30,000 square feet. Experimental water treatment and sewage treatment plants are located in a specially constructed wing which is served by lines delivering untreated sewage and raw river water.

The major projects described briefly in this report are grouped under six headings: characterization of waste, treatment of waste for disposal, disposal of waste effluents, monitoring of wastes in streams, treatment of water for reuse, and supplementation and conservation of water supplies. This is a convenient functional grouping based on the normal sequence of waste generation, treatment, disposal, and water reuse.

The merit of the present classification is that it indicates the efforts being expended in various areas, and that it may serve as a basis for an evaluation of the relative seriousness of the problem in each area. This evaluation is supplemented by Appendix A, an analysis of the man-years of professional effort devoted to these projects.

Although the text of this report concerns itself directly with water supply and water pollution research, a substantial part, approaching one-third, of available staff time is devoted to nonresearch activities, grouped under the heading "Technical Assistance."

Requests for technical assistance come from Federal, State, and interstate agencies and local agencies, and from private agencies and individuals. The response to such a request may take the form of a full-scale research project performed under contract, or the answer may be supplied immediately by a staff member.

Training is provided by the SEC Training Program. During the fiscal year beginning July 1, 1959, twelve training courses on water supply and water pollution subjects will be presented, ten at the Sanitary Engineering Center, and two in the field. These intensive one or two-week courses are based on the most recent developments in the Center's field of activities and are designed for professional personnel in sanitary engineering. Research personel regularly serve as training course lecturers.

The text that follows consists of brief descriptions of the Center's research activities in water supply and water pollution. Imparting such information is an important part of the Center's over-all responsibility. Because the Nation's pooled resource for research on such problems is small compared with their magnitude, it is desirable that communications be improved between research agencies in this field. It is believed that this objective will be advanced by the issuance of this report.

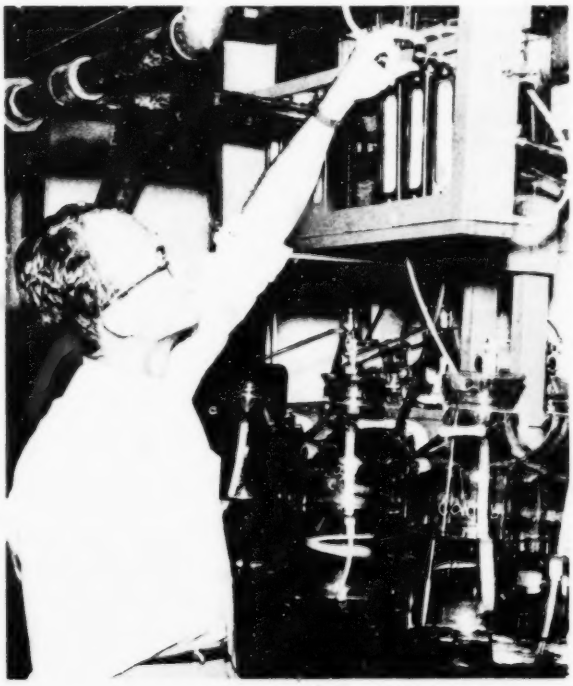
Bernard B. Berger, Chief
Research Branch

CHARACTERIZATION OF WASTES

FISH BIOASSAY STUDIES

In waste characterization, a criterion is the possible effect on aquatic life. This includes acute and chronic toxicity and the possible tainting of fish flesh.

Bioassays are used to determine directly the toxicity of chemicals or industrial wastes to fish. Reasonably simple, standardized procedures have been developed.



The major research efforts at the Center are in the development of guide lines for application of bioassay results. Investigations include those on acute versus chronic effects of toxicants, effects on different species of fishes, and the effect on toxicity of changes in water quality characteristics. Studies also are being made on the effect of certain chemicals in tainting fish flesh.

Among chemicals studied are metal salts, organic cyanides, some important industrial chemicals, detergents, and insecticides. Some studies with complex industrial wastes have also been carried out.

Results indicate that there are major differences in acute toxicity to fishes, even in closely related chemical compounds. The toxicity of inorganic metal salts is greatly influenced by dilution water characteristics such as pH, alkalinity, and hardness, but most of the organic compounds are relatively unaffected. The relative tolerances of different species of fish are dependent on the type of chemical. While the difference in tolerance of the species tested was moderate (2 to 5 times) for most chemicals, several organic phosphorus insecticides showed much greater differences. Some chemicals have a fairly high chronic toxicity and others do not.

On the basis of present information, it is apparent that to obtain reliable results, toxicity studies must be carried out with the industrial effluent of concern under conditions related to its disposal. Chemical data on waste composition cannot be used to predict accurately the toxicity of a complex waste to aquatic life. If the toxicity of the waste is determined directly, a reasonable amount of study can establish suitable application factors for safe disposal. If it is determined that waste treatment is needed, toxicity information on pure chemicals and the data on chemical composition may be necessary for the selection of proper treatment methods.

DISSOLVED OXYGEN REQUIREMENTS OF FISH AND OTHER COOPERATIVE STUDIES AT THE CORVALLIS, OREGON, FIELD STATION

Pacific Cooperative Water Pollution and Fisheries Research Laboratories at Corvallis, Oregon, developed jointly by the Sanitary Engineering Center and Oregon State College since 1953, conducts predominantly fundamental research, mostly on the ecology, physiology and toxicology of fresh-water organisms, pertinent to waste disposal problems. The work is now supported in large part by PHS and other research grants to Oregon State College.

A current intensive investigation of the dissolved oxygen requirements of fishes includes experimental studies of effects of reduced

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oxygen concentrations on survival, food consumption, and growth rates of fresh-water forms, especially juvenile salmonids; on their sustained activity potential or ability to swim against currents of varying velocity; on their movements involving avoidance reaction; and on embryonic development, hatching time and success, and post-hatching larval mortality. The influence of environmental factors such as temperature, carbon dioxide concentration, pH, and velocity of water movement on the responses of fish and their eggs or embryos to reduced oxygen concentrations is being investigated. Oxygen requirements of some aquatic insects also have been studied.

"Artificial streams" have been used in the laboratory to study the responses of various stream organisms to environmental changes caused by introduction of pulp mill wastes; and they are to be employed in connection with studies of the influence of putrescible organic and other nutrient materials on stream waters, and of resulting bacterial and other benthic growths on stream productivity.

A quarter-mile experimental section of a small, natural trout stream, subdivided with self-cleaning screens and having a controlled flow, also is to be employed as an outdoor laboratory. The effects on stream ecology and productivity of enrichment with organic matter and other factors will be studied. Attention will be directed especially to energy transfer relationships of the ecological system or unit under study. Fishery scientists, entomologists, botanists, engineers, and others are cooperating in this ambitious and costly undertaking.

The physical, chemical, and toxicological properties, sources, interactions, and relative importance of kraft pulp mill waste constituents which are toxic to fish are being investigated, and an attempt is being made to isolate and identify some of the unknown toxic compounds.

The chemistry and toxicology of complex metallo-cyanides, which can be important constituents of metal-finishing plant effluents, are under study. An effort is being made to develop a method for the determination of free, undissociated hydrocyanic acid in solutions of complex cyanides. There is evidence that the concentration of this single component largely determines the toxicity of the solutions to fish.

The toxicity of some insecticides such as Endrin to fish (SEC project) and of the effects of pulp mill wastes and other toxicants on oysters and other marine organisms (OSC projects) are being carried on at Oregon State College within the framework of the organization.

CHARACTERIZATION OF WASTES FROM SIGNIFICANT RECURRENT INDUSTRIAL PROCESSES (CATALYTIC CRACKING OF PETROLEUM)

There are two basic approaches to the measurement of the pollutional character of an industrial waste. First, the waste may be analyzed for specific compounds. The quantitative data thus obtained, together with information on the pollutional effects of the specific compounds, constitutes an appraisal of the pollutional effects of the industrial waste. The second approach considers the industrial waste as an entity. The pollutional effects of the waste are measured directly without analysis of the waste for any specific compound. The second method (the integrated waste approach) is used for the project presented here.

The opinion is commonly held at the Center that wastes from the petrochemical industry are in the greatest need of study. The industry is comparatively new; it is expanding, and is suspected of producing water pollution problems in several situations recently coming to the attention of the Center. This project was instigated with the objective of characterizing wastes from the petrochemical industry. Virtually the entire aliphatic segment of the petrochemical

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industry is based upon olefins produced by thermal or catalytic cracking of crude petroleum or petroleum fractions. Therefore, wastes from the catalytic cracking of petroleum were selected for the project.

There also has been a need to demonstrate in one application all recommended techniques for comprehensive characterization of an industrial waste. This characterization would desirably include recently perfected techniques for measuring pollution damages and should go beyond the common parameters to direct measurement of damaging effects on downstream water uses.

Prior to proceeding on the waste characterization program, it was decided that it would be necessary to make a survey of catalytic cracking wastes at a number of refineries. This survey would confirm or refute the assumption that catalytic cracking wastes of reasonably similar composition were being produced at each refinery. Four 8-hour composite samples have been obtained from five refineries. These samples have been analyzed for phenols, oil, threshold odor, sulfides and chemical oxygen demand.

The comprehensive characterization work will consist of the measurement of representative waste samples in terms of damages to specific downstream water uses. Not only will the damages be measured for the wastes as produced but (1) for the wastes after being subjected to biological treatment, and (2) after being subjected to the forces of natural purification. Thus, the treatability of the wastes will be measured in terms of removal of water-use-damaging properties. In addition, the persistence of the water-use-damaging properties under simulated stream conditions will be measured. The characterization work is currently under way. The information developed will be of interest to the more than 400 petroleum refineries in the United States and to the corresponding water pollution control agencies. A secondary value will be the demonstration to industry and regulatory agencies of the type and extent of information needed to consider properly a waste disposal problem.

DEVELOPMENT OF THE CONTINUOUS DISSOLVED OXYGEN ANALYZER

A continuous dissolved oxygen analyzer was developed commercially* based on the principles and models established by Dr. H. S. Levine and co-workers at the Sanitary Engineering Center.

The work by this manufacturer has resulted in a commercially practicable instrument which will be serviceable for the measurement of oxygen in water under many circumstances.

A report of this work is scheduled for early publication in Sewage and Industrial Wastes. Mimeographed copies of this report are available during the interim period.

DEVELOPMENT OF PROCEDURES FOR MEASUREMENT OF PHYSICAL CHEMICAL PHENOMENA AFFECTING WATER QUALITY

The traditional values of solubility of oxygen in water have been questioned by Truesdale and others in recent publications. Since the solubility of oxygen is a tremendous factor in the appraisal of oxygen sags in streams, a further appraisal of the solubility of oxygen in water by a competent investigator was sought.

A contract providing for the investigation on a limited scale of oxygen solubility in water was made with Harvard University with Professor J. Carrell Morris being designated as the responsible investigator. Limited numbers of the final report of this investigation are available. Professor Morris's re-examination of oxygen solubility indicates better agreement with Winkler than any others. Professor Morris's values are also much closer to the values proposed by Fox, which have been used as standard, than they are to those proposed by Truesdale, et al.

*Hays Corp., Michigan City, Ind.

TREATMENT OF WASTES FOR DISPOSAL

SEWAGE AND WASTE TREATMENT BY STABILIZATION PONDS

Stabilization ponds for the treatment of raw sewage have been in use in this country for slightly over ten years. Following the first designed installation in North Dakota in 1948 their use spread rapidly throughout many of the neighboring states in the Missouri River Drainage Basin. Early in this decade the Public Health Service began studies to evaluate the operation of existing facilities and to carry out controlled investigations. The aim was to develop the fundamental knowledge prerequisite to the establishment of basic design and operational criteria.

In 1955 a joint State-Federal field study was initiated on five ponds in the Dakotas. Also, in the summers of 1955 and 1956 the Service worked with the Texas State Department of Health to evaluate data in their files on some 190 "oxidation ponds" in that State. The results of these studies were as follows:

1. The treatment of raw sewage in stabilization ponds is practical.

2. Properly designed and operated stabilization ponds will provide a degree of purification comparable to that obtained by conventional complete sewage treatment processes.

3. Like any other sewage treatment device they have advantages and disadvantages and should not be considered as a panacea for all sewage treatment needs.

4. This method of sewage treatment warrants consideration in the engineering evaluation of sewage treatment needs for locations where it is applicable.

Following these field studies, controlled experiments were started at two locations to develop more rational design criteria and operating procedures. The first of these, at Fayette, Missouri, was placed in operation about January 1, 1957. The first 15 months of operation involved the loading of five one-acre ponds at 15 lb. increments ranging from 15 to

75 lbs. of 5-day BOD per acre per day. The BOD reductions showed little variation between the ponds. The 15 lb. loading showed monthly average BOD reductions ranging from 83 to 90 per cent. Pond No. 5, loaded at 75 lbs. per day, gave reductions ranging from 76 to 86 per cent. Bacterial reductions did not vary greatly from pond to pond and the coliform MPN reduction was greater than 99.5 per cent at all times. Units operated during the entire 15-month period without any odor nuisance, although ice did cover the ponds for approximately one month.

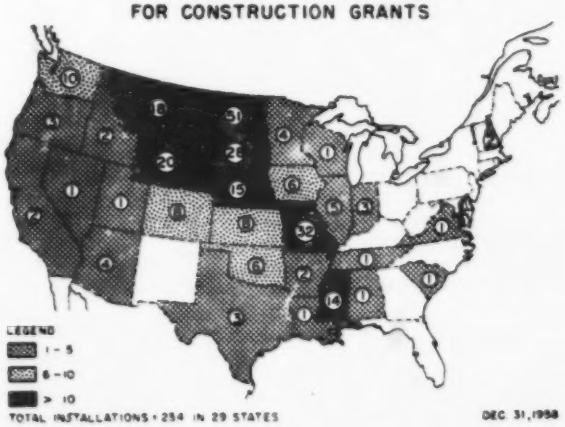
The second experimental facility is located at Lebanon, Ohio, and was placed in operation in July, 1958. Here two 1/4-acre ponds have been loaded at a rate of approximately 120 lbs. of 5-day BOD per acre per day and while there have been the usual start-up difficulties, the ponds have operated in a nuisance free condition for the entire period, even though there was an extensive period of ice cover during the past winter.

Studies indicate that it is possible to load ponds at a much higher rate than originally practiced in the Dakotas. Experience indicates that in those climates where ice coverage does not occur, even the prevalence of some anaerobic conditions for short periods of time should not lead to serious odor complaints. In fact,

less odor would be expected than from a conventional Imhoff tank-trickling filter facility. For this reason it is believed that the same general criteria can be applied with regard to locating stabilization ponds with respect to habitation as is applied in conventional treatment works.

This type of facility is being used extensively in the Chicago and Kansas City, Missouri, areas for the treatment of sewage from housing developments. In many instances it is planned to use stabilization ponds until such time as intercepting sewers can be constructed. In some cases, however, they may be considered as the final methods of sewage treatment. Various cost analyses have indicated that the per capita construction cost of stabilization ponds averages about $14.

STABILIZATION PONDS APPROVED
FOR CONSTRUCTION GRANTS



The Public Health Service has also been evaluating the use of these facilities for the treatment of various types of industrial wastes. Information is available on some 40 installations serving in at least ten different types of industries for the primary purpose of reducing the water polluting constituents of wastes. The types of wastes being treated include pulp and paper wastes, packing and slaughterhouse wastes, dairy wastes, citrus and urea wastes, wastes from chicken-processing plants, vegetable canneries, laundries, organic chemical industries, metal-working plants, and petrochemical plants. In general, results have been satisfactory, although in one instance unsatisfactory results have been experienced in an attempt to treat a mixture of domestic and textile mill dye wastes. No doubt the highly colored wastes exclude the light necessary to develop algal growths. There are a few instances where organic loadings are sufficiently high to make it impossible to maintain aerobic conditions. These anaerobic ponds have been shown to produce a greater BOD reduction per unit of surface area than in the conventional aerobic ponds, although in some instances objectionable odors have been reported.

In general, the Public Health Service believes that the stabilization pond method of biological treatment has a legitimate place in the treatment of industrial wastes. The design should be flexible so that advantage can be taken of the holding capacity of the ponds to serve as a buffer between some unforeseen condition in the receiving stream. The protection that can be afforded to the stream by such an arrangement is tremendous and provides an excellent factor of safety for any industry.

STUDIES ON BIO-OXIDATION SURFACES

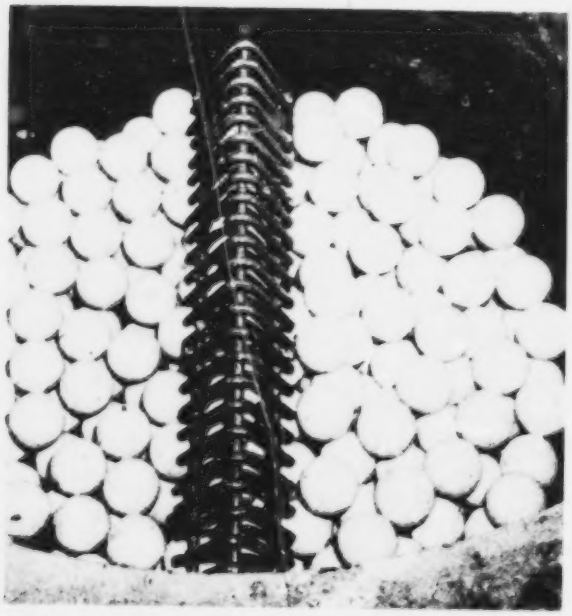
The first investigation of stone-packed trickling filters was conducted at the Lawrence, Massachusetts, Experiment Station in 1889. This treatment process has been widely adopted and biological oxidation beds are used extensively for treating domestic sewage and industrial wastes. A 1958 survey indicated that trickling filters were employed in 58% of the secondary treatment plants in the U.S. Yet, there are no generally accepted criteria for many of the design features. As a consequence, State and local officials have stressed the need for additional research.

Early researchers studied purification at low application rates on relatively small-sized media. Subsequent evaluations usually involved full scale operating plants where individual variables could not be controlled and frequently were not measured. Knowledge of individual effects of hydraulic application rate, organic loading, surface area, depth, time of passage, temperature, ventilation and waste character is sparse or non-existent. Little is known of the relationship of these variables to types and numbers of organisms, amount of film material, and efficiency of treatment.

The PHS has been concerned about this lack of information. The Service, in cooperation with the City of Battle Creek, Dow Chemical Co., Michigan Water Resources Commission, General Foods Corp., Kellogg Co., Michigan Department of Health, and Jones, Henry and

Williams, Consulting Engineers, performed a field pilot scale study using plastic media in a tall column. Results of this study were reported in June 1958.

The current SEC research approach is based on the concept that mean residence time of a waste in a filter influences treatment efficiency. Consequently, the initial pilot plant studies investigated residence time as a function of media shape, size and roughness; rate of application; temperature; viscosity; biological film; and depth. Formulas were developed relating the controlled variables to passage time. A series of columns packed with glass

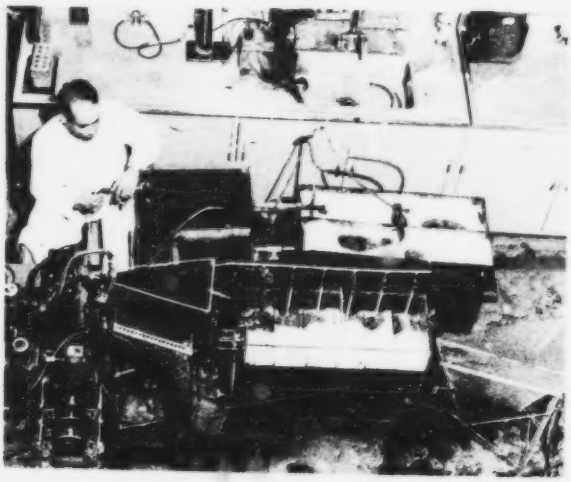


and porcelain spheres was dosed with water at various rates using salt as a tracer. A report covering these initial phases is scheduled for publication in The Journal of the Sanitary Engineering Division, ASCE.

Future studies are contemplated in order to expand on the original hydraulic investigations and to develop data under test conditions with a biological film. The physical set-up will provide for the control of the BOD load-waste characteristics, application rate, and temperature. Rates of application will vary from normal low rates to extremely high rates and filters will be sampled at various depths. Four filters will be studied simultaneously. The data will be evaluated statistically in order to correlate the hydraulic factors with passage time and passage time with purification. In this fashion the design factors may be related to BOD removal to provide more effective and economical use of the trickling filter process.

EFFECT OF TOXIC HEAVY METALS ON BIOLOGICAL TREATMENT PROCESSES

Of the various metals claimed to exhibit toxicity to biological processes, chromium is the only one studied so far. Two activated sludge pilot plants operating at a feed rate of 240 gals/day have been used. Hexavalent chromium has been added at five concentration levels; namely, 0.5, 2.0, 5.0, 15.0 and 50 mg/l level as yet.



At none of the chromium levels studied thus far, for which data are available, has the removal efficiency of BOD been affected. This removal has averaged better than 94%. COD removal has been somewhat more erratic in both units, ranging from 72 to 90% with an average of around 84%. Suspended solids removal has been excellent for both units, averaging above 94%.

At the lower chromium feeds (0.5 and 2.0 mg/l) no hexavalent chromium appeared in the final effluent. At the present time, the effluent of the chromium fed unit contains 8 to 12 mg/l of hexavalent chromium. One of the noticeable effects of the presence of chromium in the secondary settler has been the absence of nitrification. Another effect has been the prevention of the settled sludge from becoming anaerobic throughout the 24-hour period. This is not true of the control unit; the secondary sludge always is septic at the end of 24 hours.

In the aeration tank the mixed liquor contains both hexavalent and trivalent chromium.

The concentration of total chromium at the present time is above 150 mg/l. No noticeable effects on the floc have been noted. Sphaerotilus has appeared in both units at various times and the presence of chromium is apparently no deterrent to its growth. On the other hand, "red worms" have appeared in the control unit but never in the unit containing chromium.

Two digesters have been operated on a 26-day retention cycle at 30°C. These are fed daily with a mixture of primary and excess activated sludge. The chromium fed digester contains at the present time 125 mg/l of total chromium, none of which is in the hexavalent form. The presence of this amount of chromium has had no significant effect on gas production, the volume of gas of both digesters being within 10% of each other. On occasions, the chromium fed digester has produced 1.5 times as much gas as the control. The gas contains about 28% CO_2. The pH of both digesters has remained remarkedly constant (around 6.8).

A third unit using fresh activated sludge has been used for determining the effect of "slug" doses of chromium at 10 and 100 mg/l. The 10 mg/l slug showed no effect on the sludge and the BOD removal efficiency remained above 95%. The 100 mg/l dose showed no effect on the sludge itself; however, no BOD or COD removal efficiencies are available as yet.

TREATMENT OF SEWAGE BY ANAEROBIC CONTACT

A series of studies was undertaken to develop a low-cost efficient sewage treatment plant tailored to the needs of small groups of houses. Objectives are to develop a plant which will produce an effluent safe for discharge with very little dilution water and free from nuisance. The plant must be simple, dependable and amenable to operate on a very low budget. In initial cost, the plant and sewerage system must compete with individual septic tank systems.

The anaerobic system was singled out for trial because there was reason to believe that good, nuisance-free treatment could be obtained without supplying air. By eliminating the need to supply air or to maintain aerobic conditions, a plant with a minimum of mechanical equipment can be designed.

A laboratory model of an anaerobic plant making use of the sludge contact principle was constructed. The laboratory experiments were judged a success and a laboratory scale pilot plant was set up at Loveland, Ohio.

After two years of operation under severe test conditions, the pilot plant reflected a 60% reduction of COD and 82% reduction of suspended solids. The first unit of the process showed considerable promise for use as a primary treatment device.

A full scale test installation of the anaerobic contact process is underway at Peoria, Illinois. The contact process is being used for primary treatment in lieu of an Imhoff tank. The contact tank is followed by a trickling filter and a small oxidation pond. At present, 350 homes are being served by the plant and construction is continuing. Suspended solids removal has been far in excess of that to be expected in an Imhoff tank and BOD removal has been slightly better. The plant was constructed at a very low capital cost and operational requirements have been minimal.

In addition to the study at Peoria, Illinois, Ohio State University is investigating under contract the use of the anaerobic contact process followed by complete aerobic stabilization of the effluent. Under sponsorship of N. I. H. research grant funds, Professor George Schroepfer at the University of Minnesota is continuing a thorough investigation of the anaerobic contact process as applied to sewage treatment.

CONVERSION OF SUGARS IN SPENT SULFITE LIQUOR TO FUMARIC ACID

Spent sulfite liquor has long been recognized as a serious water pollutant. The pollutional effects of this waste are due principally to the presence of large quantities of fermentable sugars. It has been estimated that for each ton of sulfite pulp produced, 400 lbs. of sugar appear in the spent liquor. Therefore, a small mill manufacturing 100 tons of pulp per day may discharge as much as 20 tons of sugar per day in its waste. Thus, this waste, as well as being a serious pollutant, may also be considered as a raw material.

Fermentation processes have generally been shown to be of great value in the utilization of dilute, impure sugar solutions. The application of these methods has resulted in the production of ethyl alcohol and feed yeast from spent sulfite liquor. The process under study in this laboratory utilizes a fungus to convert

sugars in spent sulfite liquor to fumaric acid, valuable in the production of plastics and resins.

The high ratio of fermentable sugar to available nitrogen and phosphorus makes spent sulfite liquor a suitable substrate for fumaric acid fermentation, since good yields of this acid are obtained only when nitrogen and phosphorus concentrations are limiting with respect to growth. The optimum amounts of these nutrients to be added to the liquor were determined by experiment and found to be critical.

Successful fermentations have been carried out with calcium base liquors obtained from the pulping of sprucewoods. In experiments to date, 87 per cent of the total sugar has been removed with a weight/weight conversion to fumaric acid of 41 per cent, giving a total yield of 36 per cent. Experiments are in progress to determine optimum fermentation conditions for the purpose of increasing yields and shortening fermentation time. The ultimate applicability of this process can be determined only after experimental answers to the following questions have been developed: (1) How rapidly can this fermentation be carried out? (2) Can fermentations with concentrated liquors be carried out efficiently? (3) Is a continuous process feasible? (4) How economically can the fumaric acid formed be recovered?

STREAM STUDIES - SELECTION AND ADAPTATION OF MICROORGANISMS TO DEGRADE SPECIFIC ORGANIC WASTES

A highly significant percentage of the by-products of the diversified petrochemical industries, paper mills, textile plants and other related industrial operations, disposed of as effluents into water-courses, are persistent waste materials which are relatively resistant to microbial attack. Such by-products include lignins, which are among the persistent hydrocarbons most resistant to microbial action, particularly in their isolated state.

The purpose of this study is to investigate the capacities of bacteria to dissimilate the persistent hydrocarbons using selected organisms isolated from natural sources; to assay the potentials of some of the culture enrichment, acclimation and adaptation methods to yield organisms with improved metabolic capacities for utilizing them; and to study the pathway of microbial metabolism of these hydrocarbons by isolating the products of dissimilation. Selection and adaptation techniques are employed in isolation of bacterial strains that are genetically and physiologically better adapted to utilize the persistent waste materials is emphasized.

Problems Created by Lignin Wastes
Impart color to water
Ruin fish spawning beds
Ruin shellfish beds
Destroy normal flora and fauna
Increase waste treatment problem
DIFFICULT TASK TO BIOLOGICALLY TREAT LIGNIN WASTE
LIGNIN WASTE RESISTANT TO MICROBIAL ATTACK

The utilization of lignin related compounds seems to be a frequent characteristic of the genera Pseudomonas, Flavobacterium and Achromobacter and isolation of the lignan degrading bacteria from widely separated points indicates their broad geographical distribution in a variety of environments in nature. The Pseudomonas species were found to be most numerous and most active of all the lignan utilizing organisms. The alpha-conidendrin metabolized by mixed cultures at the end of 20 days ranged from 64 to 95 per cent. Pure cultures utilized from 57.75 to 92.17 per cent of alpha-conidendrin in 20 days.

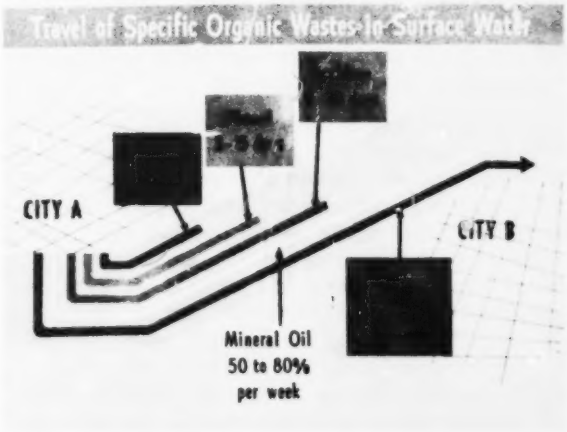
Simultaneous adaptation studies, together with chromatographic and spectrophotometric analyses of the degration products revealed that the metabolic pathway appears to proceed from alpha-conidendrin — vanillic acid — para-hydroxybenzoic acid — protocatechuic acid — beta-ketoadipic acid.

TREATABILITY AND PERSISTENCE OF SPECIFIC ORGANIC COMPOUNDS

The primary objective of these studies is to expand the catalogue of organic compounds associated with industrial wastes on which data are available for biological purification in surface water and treatment systems. A fundamental assumption in these studies is that an organic compound will respond similarly, regardless of the associated materials, so long

as some component does not completely sterilize the mixture. A phenol, for example, will behave much the same in refinery, coke plant, chemical process, or other industrial effluents.

Groups of compounds are selected for study because of their commercial importance or their history of appearance in waste effluents. Each group has a common functional entity with different associated radicals. These are investigated in surface water and conventional treatment to determine the pattern of biological



self-purification of the common functional entity and the structural variations within the group. The results should be useful to predict behavior of other groups that have not been studied. Work on hexadecanol can be used to verify this approach. This compound used for evaporation suppression tests in water reservoirs was claimed to be biologically inert. Its structure indicated that this was highly unlikely. Experimental work (A.W.W.A., 49, 7, 849, 1947) established that it was readily consumed for metabolic energy and set out the pertinent variables controlling this action.

Nitrile compounds have been studied and plans are under way to investigate vinyl materials.

The nitrile group included six compounds having a common organic cyanide radical. Materials investigated included acetonitrile (saturated aliphatic), acrylonitrile (unsaturated aliphatic) benzonitrile (aromatic) lactonitrile (electronegative group) adiponitrile (aliphatic dinitrile) and oxydipropionitrile (dinitrile ether).

The group was investigated with bench scale experiments in surface water, activated sludge and anaerobic digestion for information on acclimation, loading, and biological, chemical or physical variables affecting performance. Surface water results were reported. (Sew. and Ind. Wastes, 31, 1, 33, 1959).

Treatment system performance is in the first draft stage of reporting. All of the nitriles tested responded to aerobic biological action after acclimation periods varying with the particular nitrile. Activated sludge treatment acclimation was appreciably more rapid than in surface water. Anaerobic treatment cannot be recommended.

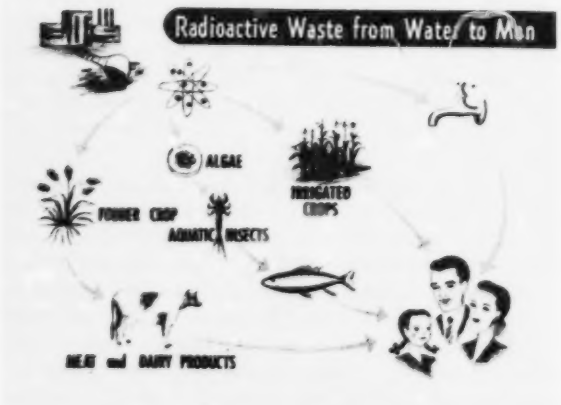
CLAY-POLYELECTROLYTE TREATMENT OF OIL BEARING WASTES

A process of treatment of oil-bearing wastes by clay and synthetic polyelectrolyte flocculating agents was conceived and investigated by the Center's research personnel. The adsorption of oil by clay has been previously observed but utilization of such phenomena for waste treatment was impractical because of difficulties in removing the clay. Furthermore, the effectiveness of clay treatment in oil removal was not high. The ability of newly developed synthetic organic polyelectrolytes to flocculate clay was also known. The combination of these phenomena, supposedly through the route of adsorption of the oil on clay and subsequent flocculation of the clay by the polyelectrolyte, held promise of an effective treatment.

The six commercially available polyelectrolytes tested varied in their effectiveness in removing emulsified oil. Only one of the six polyelectrolytes tested was of significant effectiveness in treating prepared emulsions of motor oil in tap water. Another of the six was significantly effective in treating one petroleum refinery waste. None of the six was effective for a second refinery's waste. Unknown characteristics of the carrier wastes and the emulsion evidently are controlling factors. Cost estimates based on the successful results indicate an economical advantage over present chemical coagulation treatment. Further investigation of the process appears most logically to be on a case by case basis. The potentials of more easily filterable sludge and reduced sludge volume would be explored in such trials.

STUDIES OF WASTES FROM THE URANIUM ORE REFINING INDUSTRY

Extraction of uranium from the raw ore results in considerable amounts of long-lived radioactive waste products, including radium. Beginning in 1955, studies have been made of the fate of such wastes in stream environments. In 1957, studies of the uranium mill processes as they affect the waste disposal problem, began with a field investigation of the resin-in-pulp extraction process in a uranium refinery at Edgemont, South Dakota. Early in 1958 the Atomic Energy Commission expressed its interest in this phase of the activity and since that time has supported, in part, the development of an industrial waste guide for the uranium refining industry. The general industrial waste study includes these specific objectives: characterization of wastes arising in representative mills as to quality and quantity, and in terms of radioactivity, chemical toxicity, persistence in the environment, and other characteristics. To some degree the studies also involve appropriate techniques of waste disposal, possible process modification desirable for efficient waste disposal, and stream dilution requirements in terms of local water uses, other sources of radioactive exposure, and existing standards.



It is hoped this guide will provide a basis for judgment of appropriate locations of any new uranium mills, as well as for adequate waste disposal practices at existing mills.

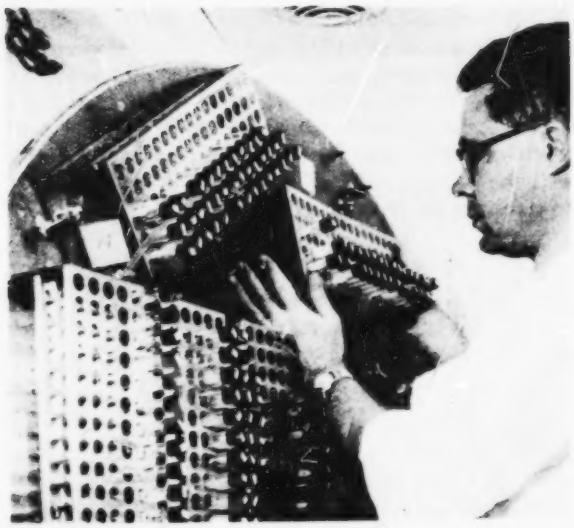
The primary studies involve in-plant investigations of refinery process streams, including wastes, in mills representative of the several ore processing techniques now in use. Emphasis is on the most modern processes and those likely to be in use for some years. Process flow diagrams are developed, key sampling points selected, and composite samples collected for analysis. Flow measurements are made whenever possible. Because radium is the most hazardous radioisotope involved, an attempt is made to develop a radium balance through the plant, both as soluble and insoluble radium. Fish toxicity studies are carried out if they appear desirable at any particular site. Production figures for the survey period and a pre-survey period of some length, water consumption figures, ore quality and type, process modifications that may be keyed to the ore type, and any process changes or expansion anticipated in the future, represent information supplied by mill management.

To date, five field surveys have been completed in operating refineries. Two of these refineries used the acid leach resin-in-pulp extraction process, an ion exchange technique. The other three mills employed the acid leach solvent extraction process, which depends upon the relative solubility of uranium in different solvents. Two of the latter mills are also vanadium producers. Analysis of samples from these field surveys is presently in progress. It is anticipated that two more field studies probably will be necessary in order to characterize the wastes from mills utilizing a carbonate leach process.

ROLE OF WATER IN THE TRANSMISSION OF VIRAL DISEASES

The rapidity with which new enteric viruses are being described re-emphasizes the potential problem of water-borne virus disease. In 1948 only those viruses producing poliomyelitis and infectious hepatitis were known to be present in human feces. Since that time, more than 70 enteric viruses have been demonstrated in feces. Many of these viruses also have been isolated from urban sewage. The effectiveness of current water and sewage treatment processes in removing or destroying enteric viruses is largely unknown. The recent water-borne epidemic of infectious hepatitis in New Delhi, India illustrated the need for more information and improved methodology in this field.

Several years ago the Sanitary Engineering Center began studies on the occurrence and persistence of viruses in water and sewage and the removal of viruses by conventional treatment processes. The resistance of enteric



viruses to chlorine appears to be variable. For example, a strain of Coxsackie A2 virus required 10-50 times as much free chlorine for inactivation as was required to kill E. coli bacteria. On the other hand, Adenovirus type 3 was inactivated by chlorine as readily as E. coli cells. Wide differences have also been observed in the amounts of iodine required to inactivate different viruses in water. The survival time of Coxsackie virus in various waters has been observed to be as long as 47 days in grossly polluted water; survival times appeared to be directly related to the degree of pollution. Detailed experiments on the effectiveness of alum or ferric chloride flocculation as a method of removing viruses from water showed that more than 95% of added Coxsackie virus could be removed by careful flocculation.

Investigations of the following problems are currently in progress or in proposal.

a. The effectiveness of sewage treatment processes in removing selected enteric virus from sewage.

b. The relative survival times of coliform and enterococci bacteria and certain enteric viruses in various waters.

c. The relative resistance of coliform and enterococci bacteria and certain enteric viruses to chlorine.

d. Development of better methodology for the enumeration of virus in water and sewage.

e. Development of a laboratory method for the cultivation of the virus of infectious hepatitis.

ROLE OF FUNGI IN ENVIRONMENTAL SANITATION

By microscopic, macroscopic and cultural observations it has been shown that filamentous fungi and yeasts are among the most commonly occurring organisms in the sewage treatment biota. The filamentous fungi form an important part of the binding materials in the slime on trickling filter stone. Nutritionally, the commoner of these filamentious fungi can supply their own vitamin needs but compete with other organisms for most carbon and nitrogen containing compounds, and for dissolved oxygen supplies.

Included in the group of fungi are molds whose occurrence in nature is ubiquitous, being found in soil as well as in polluted water and sewage. The nature of some of these organisms is better understood when their relationships with similar organisms are more clearly defined. For these reasons, studies in the identification of atypical strains and species taxonomy must be undertaken. This is especially true in relation to yeasts, yeast-like organisms, and and false yeasts, which find an excellent habitat on trickling filters, but for which the cultural characteristics and criteria of identification are not well known. Studies of this type continue to require time and attention.

In nature some fungi utilize lignin as a source of carbon and are responsible for the relatively slow decomposition of litter and wood. It would appear, therefore, that they might be able to break down ligno-sulfonates and other wood processing wastes. Experimental laboratory growths to date, however, are more closely related to the presence of sugars in the wastes than to the modified lignin content.

Large numbers of many fungal species are normally present in soil. Preliminary observations indicate that these soil fungal populations may be considerably modified as to number and species by septic tank drainage and

other types of organic wastes. In this respect distinct changes in soil populations have been noted in soil samples from Michigan which received Kraft waste liquor by spray irrigation. It is proposed to study additional samples to determine the effects of such materials on populations down to a depth of 20 feet.

Additional studies are anticipated in which the abilities of selected species of filamentous fungi and yeasts, in pure culture and in combination, to metabolize resistant organic materials will be determined. It is also expected that the growth efficiencies of these organisms will be compared in aerobic systems and in environments free of oxygen.

DISPOSAL OF WASTE EFFLUENTS

STUDIES OF SOIL ABSORPTION OF LIQUID EFFLUENTS

The disposal of liquid wastes into soils or subsoils is receiving increasing attention since surface waters, the conventional disposal medium, are becoming overloaded. The use of soil offers one possibility for reducing this load. In the ever expanding industrial and housing development, surface waters are not always conveniently and economically available, so that communities are being forced to other disposal techniques. The wide use of septic tank-soil absorption systems, increasing use of small sewage treatment plants with disposal to dry or near-dry streams are prime examples of forced use of soils. Industrial waste disposal through a combination ponding and soil filtration and through irrigation techniques is increasing. Despite the widespread use of soil and the indicated increasing use, the science of using the soil to obtain optimum efficiency is weak.

Two separate problems are inherent in the use of soil for waste disposal (1) the problem of ground water pollution, (2) the problem of adsorption at the soil-liquid interface.

Studies of individual household soil absorption systems being conducted at the Center and financed by the Federal Housing Administration permit the study of effluent absorption at the soil-liquid interface. The mechanics of clear water absorption and theories of effluent absorption also are being investigated, leading to the development of a rational mathematical model relating the use of soil area to the soil characteristics, time of use, and a soil clogging parameter. Application of the model to the broader problem of general use of soils for liquid waste disposal is indicated.

STUDIES OF MICROBIAL CONTAMINANTS IN STREAMS

In addition to saprobic soil and water microorganisms, sewage contains coliform organisms and enterococci as well as (intermittently at least) pathogenic enteric bacteria, tubercle bacilli, fungi, viruses and parasites. Although sewage treatment processes remove perhaps the major portions, some of these organisms are present in the effluents and represent potential health hazards to persons in intimate contact with the receiving waters.

Bacteria: Current studies seek to determine the coliform type distribution in feces of humans and domestic animals, in sewage and soils; also to assay the fecal streptococci in the same habitats to serve as bases for evaluations of pollutional indicators. In another project, the relative efficiency of chlorine in the destruction of coliforms and fecal streptococci and the relationship of chlorine residuals to survival of indicator organisms are considered.

Fungi: Fungi are ubiquituous in soil, sewage and polluted water and undoubtedly participate in the reduction of waste materials. True aquatic molds are also widely distributed; however, they are present in lesser concentrations and do not appear to be important in purification processes. Molds of a stabilization pond and of a sulphite liquor spray disposal area are being identified and enumerated. Yeasts are also constant constituents of sewage and polluted water populations. They are present in large numbers, and represent many genera and species. The identification, nutritional requirements and growth characteristics of this group are currently being studied.

Viruses: In the past ten years, approximately 70 new "human viruses" have been recognized. More than half of these are associated with the intestinal tract, i.e., enteric viruses which are excreted in feces and are readily demonstrated in sewage. The efficacy of activated sludge treatment in the removal of coxsackie and poliovirus is being investigated. Preliminary data indicate that the major portions of the viruses are removed. The relative resistances of coxsackie, polio and Echo 7 viruses to iodine are being determined. This study is not only yielding data on the disinfecting action of iodine, but is developing improved methods for the enumeration of viruses.

MONITORING OF WASTES IN STREAMS

RAPID METHODS FOR THE ENUMERATION OF BACTERIAL INDICATORS OF CONTAMINATION

The coliform group has long been used as an indicator of pollution in sanitary bacteriology. Unfortunately, the coliform test procedure does not separate the members of the coliform group into those of fecal and non-fecal origin. Further biochemical tests are necessary for such differentiation. Identification of fecal coliforms by the elevated temperature procedure appears to offer much promise.

In this country the two most frequently used elevated temperature tests are the boric acid lactose broth (BALB) procedure and the EC broth procedure. Recent evaluation of these two methods has indicated the procedures give comparable results of 93% to 99% efficiency in differentiating coliforms from fecal and non-fecal sources. In the examination of human feces, 11 of the possible 16 coliform types were found with 82% being ++-- and 8% --++. Fewer types are found in animal feces with the per cent occurrence of ++-- varying from 95% to 100%.

In view of the excellent agreement of either the EC or BALB test with fecal coliform bacteria and taking into account the saving in time and effort, the EC is the most rapid method for identification of fecal coliform bacteria. Elevated temperature procedures are recommended only when used to confirm the positive presumptive tubes of the coliform multiple tube test. Prior research has indicated the need for an enrichment period in lactose of LST broth to get optimum recovery of all levels of fecal coliforms that might be present in a water sample.

Further research with the elevated temperature test will involve a study of coliform types in the soil which may contribute coliform pollution to water resources during runoff. The examination of local soil samples indicates the fecal coliform flora to be low except in areas subject to frequent flooding by heavily polluted waters. However, due to the extreme variability of environmental conditions, soil types and differences in predominating coliform types, this study can only have value if it is possible

to examine samples from various parts of the United States.

EVALUATION OF THE ENTEROCOCCUS AND PSEUDOMONAS GROUPS AS INDICATORS OF POLLUTION

Although a tentative method for the detection of Pseudomonas species in polluted water has been achieved, it was found that Pseudomonas organisms are not found consistently in human fecal samples. Since Pseudomonas organisms are found so widely spread in nature it is not feasible to use the genus as an indicator of fecal pollution at this time. A differential test for the Ps. aeruginosa (pyocyanea) is not available at present.

A highly productive and selective medium (K-broth) for the detection of fecal streptococci from polluted waters has been developed. This medium can be used in fermentation tube tests (MPN) and MF studies. Over 1,000 colonies have been picked from MF cultures on this new medium and all have proven to be fecal streptococci. In human fecal samples studied, 70-80% of all the streptococci have been Str. fecalis as defined by Bergey's Manual of Determinative Bacteriology, 7th Edition. In

animal feces (bovine, porcine and ovine), the predominating species of fecal streptococci have been Str. bovis, Str. fecalis variants (Str. faecium, etc.), and Str. acidominimus. Biochemical procedures for the classification of fecal streptococci have been developed as an aid in their classification. On the basis of present data, the high percentage of Str. fecalis in human feces, and the relative absence of Str. bovis and other variants suggests that it is possible to identify the various sources of water pollution. On the basis of comparative studies of 25 different water sources (rivers, lakes, wells, etc.) with the various media presently available in dehydrated form, K-broth medium was found to give much higher results in the detection of fecal streptococcus pollution. In the new MPN procedure it is not necessary to run confirmed tests. Future investigations propose a study of the survival of the streptococcus in waters of good and poor qualities, enumeration of streptococcal densities in soils and the development of a delayed incubation test for streptococcus.

EFFECT OF FREE AND COMBINED AVAILABLE CHLORINE ON INDICATOR BACTERIA IN POLLUTED WATER AND SEWAGE

A variety of samples of polluted river water and sewage have been studied for the effect of chlorination on the indicator organisms of pollution. The organisms used in the preliminary investigation were the coliform group, the EC positive portion of the coliform group, and the enterococcus group. Some difficulties were encountered in the orthotolidine and starch-iodide tests for chlorine in sewage samples but satisfactory data were obtained by the amperometric method. Chlorine was applied in small quantities so that the relative bactericidal effect could be measured on the various indicator organisms used to measure pollution.

Sufficient data are not available to form any conclusions about the bactericidal action of chlorine on the organisms studied. However, the results indicate that application of chlorine reduces the EC positive portion of the coliform group more rapidly than the intermediate-irregular coliform group. Compared to the susceptability of the coliform group, the enterococci appear to be much more resistant to the effects of chlorination. Future plans include the determination of the most resistant of the pollution indicators (which appears to be the enterococcus group) and comparison of the survival of this indicator organism with typical enteric pathogens which might be expected to occur in sewage. The survival of the most resistant organisms to both artificial and natural purification processes offers an interesting field for investigation.

SIGNIFICANCE OF PROTOZOAN AND METAZOAN ORGANISMS IN WATER

The biological examination of water and water supplies for determining the sanitary quality and efficiency of water treatment has been chiefly bacteriological. The identification of living nematodes in tap water in a city using the Ohio River as a raw water source raised the question as to the sanitary significance of the presence of free-living worms and protozoa in water supplies. The most important implication is that relatively large, but still microscopic, living organisms may still be present in a finished water which is satisfactorily treated as judged by chemical, physical, and bacteriological standards when relatively large samples are examined.

To determine the significance of nematodes in water supplies, a survey was planned to study the presence of nematodes and other zoological organisms in water supplies of cities that draw their raw water from rivers. Beginning in November 1958, 2.5-liter samples of both the raw river and the finished water were collected from each municipal supply were concentrated by the MF technique for zoological organisms. Both direct microscopic and cultural methods were used in the examination. Of the examinations so far made on 10 water supplies, the following findings are of interest:

All but two supplies showed free-living nematodes and amoebae in both the raw and finished water. Most of these organisms were alive in the raw water and some of them were alive in the finished water, as judged by the motility of the worms and positive cultures of the amoebae.

The majority of the nematodes found were phasmids of the genera Rhabditis, Diplogaster, Cheilobus and Aphenelchus. Among the aphasmids, Monhystera sp. occurred three times and Anguillula sp. once. Most of the amoebae isolated belonged to the genus Hartmannella. On only one occasion was the species Naegleria gruberi, a flagellate-amoeba, encountered.

These nematodes are highly resistant to free chlorine. While the adults and older larvae may settle out in a sedimentation basin, the young larvae may remain suspended in the settled water and penetrate the rapid sand filters and find their way into the distribution system. Amoebae cysts are considerably more resistant to the action of free chlorine than vegetative bacteria but less than these nematodes. These cysts are usually largely removed by flocculation if it is satisfactorily carried out. Their presence generally indicates inefficient flocculation procedures.

While these nematodes are generally considered as soil organisms, they have been found in large numbers in trickling filter effluents, and their presence in relatively large numbers may indicate sewage pollution.

This survey is continuing.

STUDIES ON ORGANIC CONTAMINANTS

Organic contaminants of natural and industrial origin can and do affect water quality. Damages from organic compounds include taste and odor, toxicity to plant or animal life in the stream, and interference with water treatment for domestic or industrial use. It is the function of the Organic Contaminants Unit to evaluate water quality affected by these compounds by carrying out isolation and identification procedures. This information can then lead to assessment of the pollutional effects of the materials and provide a basis for corrective treatment, if necessary. Collection and detection techniques are applied to the following types of compounds:

1. Detection and analysis of known or suspected additives to water. Various organics fall into this class including cetyl alcohol for evaporation control, various organic formulations for the control of fish in reservoirs and waters, and treatment chemicals. Additives that may occur in water as a result of use include detergents and a variety of insecticides.

2. It is of importance and interest to monitor the Nation's water for unknown components. Since most of these materials are present in low concentrations, special techniques are necessary for their isolation and identification. Compounds which have been found in water using these techniques include DDT, phenyl ether, orthonitrochlorobenzene, nitriles, a variety of substituted benzene materials and others. We are presently engaged in attempting to detect the presence of polynuclear compounds which may be present in our waters. Oily pollutants from gasoline to grease represent a large problem.

3. Since none of the techniques ordinarily used measure all of the organics in water supplies, additional research is being conducted to obtain a more comprehensive knowledge of total organic contaminants. This includes materials which would not be ordinarily measured by common extraction and carbon filter techniques.

Studies are often hampered by the small amounts of organics present, and steps have been taken to secure larger quantities by the use of a large-scale field sampling carbon filter apparatus and a companion extraction apparatus. These pieces of apparatus are to be activated in the very near future.

We have considerable interest in utilizing and improving odor threshold measurements in order that more widespread use can be made of this test for tracing and evaluating taste and odor problems in wastes and water supplies.

In summary, it is our aim to carry on broad-scale evaluation of the role of organic contaminants as they effect water quality, utilizing all of the techniques and equipment available to us.

SEROLOGICAL IDENTIFICATION OF WASTES COMPONENTS

Waterborne wastes from the fermentation industries are difficult to differentiate from natural biological metabolites that occur in streams. It is difficult to identify such wastes after they have left their source. The antigenic components could furnish means for positive identification by immunochemical methods. For example, specific antisera against whey proteins and/or casein could serve to trace milk-processing industry wastes.

To date it has been shown that cell-free filtrates from certain strains of coliform

organisms, streptomyces and molds contain antigenic material even when grown on nonantigenic nutrients. It has further been shown that these antigenic components are sufficiently stable to permit recovery from river water in microgram quantities. The wastes from a small cheese plant located on a stream that has an annual average flow of five cubic feet per second was traced 0.4 mile by the use of an antisera against casein. This field trial indicated a need for a method of isolating proteins in minute amounts from large volumes of water.

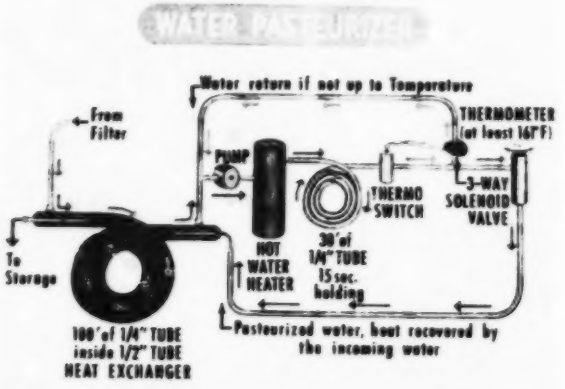
As a new approach to the problem of identifying chemical pollutants, the serological method could be extended to identify certain organic compcnents. Landsteini in 1936 found that many organic compounds, although not antigenic themselves, would produce antibodies when conjugated to a protein. The organic chemical can then be detected by its suppression on the antigen-antibody reaction.

TREATMENT OF WATER FOR REUSE (RECLAMATION OF WATER)

SMALL WATER SUPPLY SYSTEMS

The primary objective of this project is the development of a simple, reliable, and economical method of treating water from farm ponds or similar surface sources for use as a domestic supply. In order to eliminate the problems and difficulties associated with the use of chemical disinfectants, the use of heat for disinfection of water has been investigated.

A small water pasteurization unit has been developed which is capable of treating 250 gallons in 12 hours. This should be adequate for the needs of a normal family of 5 with a 100% excess capacity for greater than average demand. A heat exchanger which recovers all but 10°F of the heat permits pasteurization at 161°F for 15 seconds with reasonable heat input.


WATER PASTEURIZER
Water return if not up to Temperature
From Filter
PUMP
THERMOMETER (at least 161°F)
THERMO SWITCH
3-WAY SOLENOID VALVE
To Storage
HOT WATER HEATER
30' of 1/4" TUBE 15 sec. holding
100' of 1/4" TUBE inside 1/2" TUBE HEAT EXCHANGER
Pasteurized water, heat recovered by the incoming water

The total cost of treating water by this process should be of the order of $1 per 1000 gallons, including both fixed and operating charges. The equipment is automatic, requires very little maintenance, and no routine operation. One such unit has been in operation on a farm pond near Cincinnati for approximately 8 months, and it is anticipated that additional units will be started elsewhere in the near future. This same equipment would, of course, be equally useable in disinfecting contaminated ground water.

In the unit already installed slow sand filters have been used for clarification prior to disinfection. Although these are useable in many situations, they will not produce a well clarified water when a significant amount of colloidal turbidity is present. It will be necessary to develop some better device where the removal of colloidal material is required. It is hoped to avoid the use of coagulants such as are used in municipal practice because of the operating problems associated with dosage control and chemical feeding.

FUNDAMENTAL FACTORS IN FUNCTIONING OF GERMICIDAL AGENTS; DISINFECTING EFFICIENCIES OF SILVER

The disinfecting action of silver and other heavy metals against various pathogenic organisms was described in the German literature nearly 70 years ago. Since then, silver disinfectants have had numerous applications including use at various times for water sanitation. Recent developments have stimulated renewed interest in silver, particularly for small water supplies and for other situations where conventional treatment is inconvenient or impractical. Some of the recently proposed silver treatment systems are relatively inexpensive, require little maintenance, leave no bad tastes or odors in water, and appear to satisfactorily remove the indicator organisms of pollution.

Several chemical and bacteriological test methods have been under investigation in these laboratories. Silver is very active, both biologically and chemically, in very small amounts. For this reason there are many interferences and the biological and chemical data are often quite variable.

By using radioactive silver nitrate in a series of identical bacteriological tests, it was found that silver concentrations were sometimes reduced as much as 50% by adsorption on the glassware. The effective concentration can also be reduced by organic matter and various salts, including some buffers, which form complexes with silver. Good reproducibility has been obtained in bacteriological tests with silver nitrate when experimental conditions were rigidly controlled and concentrations were corrected for adsorption of silver by the test flasks. Silver is less active against bacteria at low temperature and low pH. For example, lowering

the pH from 6.5 to 6.2 may reduce the activity by as much as two-thirds.

Two problems have not been satisfactorily resolved. One is the reputedly greater efficiency of certain proprietary preparations over other forms of silver. The other, and more important one, concerns the bacteriostatic effect of silver. Samples of silver treated water may show no viable bacteria when an inadequate neutralizer is used in the tests, while in the same sample surviving bacteria can be demonstrated several hours after treatment if an adequate neutralizer is used. What happens, then, to bacteria that are ingested during this bacteriostatic phase? A satisfactory answer to this last problem must be supported by adequate laboratory data.

In addition to investigating the problems posed above, further work will emphasize the refinement of analytical procedures and the effects of environmental variants on the germicidal efficiency of silver.

STUDIES ON NUISANCE ORGANISMS

Microorganisms in water which interfere with its treatment or with its household, industrial, or recreational uses are known as nuisance or interference organisms. Many of them are algae but filamentous bacteria, protozoa, crustacea, and others also are implicated. They affect the water supply by bringing about chemical and physical changes which in many cases lower its quality and complicate its treatment. Because of the many different effects on the water supply and the many kinds of organisms involved, a large staff would be required to investigate these. Present studies here include work on odor production by nonfilamentous green algae and actinomycetes, procedures for detection and enumeration of algae, determination of the extent of the interference organism problems in the United States, and the preliminary screening of potential algicides.

Special attention has been given to the relation of algal lipides to odor production. The lipide content and the odor increase with age of the cell. Lipides and free fatty acids released into the water from the algal cells appear to be in part responsible for a strong grassy to tallowy odor. The earthy odor produced by actinomycetes may reach a threshold odor as high as 50,000 in cultures, and when partially purified, the components are so concentrated as to have odor threshold numbers as high as six billion. Indications are that these odor components are basic in nature since the odor is decreased by acidification.

The types, extent, and present methods of dealing with problems caused by interference organisms have been studied for three regions, the Chesapeake area, Indiana, and New England, and plans are prepared for extending the study to additional regions. The manual on algae is now completed and should be ready for early release from the Government Printing Office. The manual will contain six color plates of algae, numerous line drawings and a key for identification.

SUPPLEMENTATION AND CONSERVATION OF WATER

EFFECT OF IMPOUNDMENT ON DISSOLVED OXYGEN

Serious stream sanitation problems following impoundment have been caused by low dissolved oxygen content in water discharged from the depths of stratified storage reservoirs into the stream below. Unless corrective measures are developed and applied, severe financial burdens can be imposed on municipalities and industries by the high degree of waste treatment necessary before discharge into such streams.

Various corrective measures have been tried both experimentally and in actual practice. Of the various methods, one that appears to hold considerable promise is the elimination of stratification in storage reservoirs by recirculating the water through application of sufficient energy to mix the warm and cold strata. This would permit dissolved oxygen introduced by natural reaeration to circulate to the bottoms of the reservoirs, and assure oxygen in the water drawn from the impoundments. Mixing and circulation of water in several small reservoirs has been accomplished by both pumping and introduction of air under pressure. The Public Health Service has a project under way to investigate application of the pumping method to a reservoir several times larger than any previously involved.

CONSERVATION AND REUSE OF WATER

Emphasis is being placed on persistence of contaminants in ground water, with special efforts being made to collect unpublished information on ground water pollution incidents, particularly those in which ABS has been involved. A brief summary of known incidents has been prepared and is being distributed to the states in an attempt to increase their interest.

In cooperation with the Peoria Laboratory of the Illinois State Water Survey, limited studies are being made of the organics recoverable from recharge water and waters from wells located 200 and 1000 feet from the recharge pits. Limited laboratory studies to determine what, if any, influence ABS contamination has on distance of travel of bacterial pollution are under way.

The work to evaluate the inclusion of a bactericidal agent in hexadecanol used for evaporation control has been completed. A paper has been prepared and submitted for clearance for publication. Results were included in the Bureau of Reclamation's Report "Water-Loss Investigations: Lake Hefner 1958 - Evaporation Reduction Investigations. Report by the Collaborators." A more detailed report will be published later.

Activities on reclamation of water from sewage and saline water at present are largely limited to noting references of interest.

Appendix A

MAN-YEARS OF PROFESSIONAL EFFORT DEVOTED TO SELECTED PROJECTS OF THE WATER SUPPLY AND POLLUTION CONTROL RESEARCH BRANCH

	Year initiated	Approximate total no. of man-years of effort to date (cumulative)	Current Rate of effort (man-years in FY 59)
ORIGIN OF WASTE			
No Projects	-	-	-
CHARACTERIZATION OF WASTES			
Fish biossay studies	1953	10	3
Dissolved oxygen requirements of fish and other cooperative studies at Corvallis field station	1954	13.5	3
Characterization of wastes from significant recurrent industrial processes (catalytic cracking of petroleum)	1958	1	1
Development of the continuous dissolved oxygen analyzer	1957	3	0
Development of procedures for measurement of physical chemical phenomena affecting water quality	1958	0.5	0.4
TREATMENT OF WASTE FOR DISPOSAL			
Sewage and waste treatment by stabilization ponds	1955	9	2
Studies on bio-oxidation surfaces	1956	4	0.5
Effect of toxic heavy metals on biological treatment processes	1956	9.4	4
Treatment of sewage by anaerobic contact	1955	7	2+
Conversion of sugars in spent sulfite liquor to fumaric acid	1958	2.5	0.5
Stream studies - selection and adaptation of microorganisms to degrade specific organic wastes	1956	4.8	1

	Year initiated	Approximate total no. of man-years of effort to date (cumulative)	Current Rate of effort (man-years in FY 59)
Treatability and persistence of specific organic compounds	1950	21	3
Clay - polyelectrolyte treatment of oil bearing wastes	1957	1.5	0
Studies of wastes from the uranium ore refining industry	1958	3.1	2
Role of water in the transmission of viral diseases	1953	21	5
Role of fungi in environmental sanitation	1951	15	3
DISPOSAL OF WASTE EFFLUENTS			
Studies of soil absorption of liquid effluents	1956	24.8*	11*
MONITORING OF WASTES IN STREAMS			
Rapid methods for the enumeration of bacterial indicators of contamination	1954	17	3.5
Evaluation of the Enterococcus and Pseudomonas groups as indicators of pollution	1958	2.6	1.5
Effect of free and combined available chlorine on indicator bacteria in polluted water and sewage	1957	3	2
Significance of Protozoan and Metazoan organisms in water	1957	1.8	1
Studies on organic contaminants	1949	38	4
Serological identification of waste components	1956	7	3
TREATMENT OF WATER FOR REUSE (RECLAMATION OF WATER)			
Small water supply systems	1955	5	1
Fundamental factors in functioning of germicidal agents; disinfecting efficiencies of silver	1957	4	3
Studies on nuisance organisms	1950	25.5	4.5
Fundamental studies on chemical coagulation	1954	5	1
Studies on removal of soluble organics	1955	5	3

*Cooperative Project for F.H.A.

	Year initiated	Approximate total no. of man-years of effort to date (cumulative)	Current Rate of effort (man-years in FY 59)
Analysis of filter design criteria	1958	3.5	3.5
Removal of coliform organisms	1954	3.5	0
SUPPLEMENTATION AND CONSERVATION OF WATER			
Effect of impoundment on dissolved oxygen . . .	1956	1.7	0.5
Conservation and reuse of water	1958	1+	1
Total Man-Years of Effort		274.7	73.9